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LUBRICATION: A REVIEW

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Abstract

Use of cutting fluids in machining processes can reduce the cutting temperature and provides lubrication to tool and work piece. These translate to longer tool life and improved surface quality. Metalworking fluids are a major cause of health hazards for operators apart from being sources of environmental pollution thus necessitating research in dry and minimum quantity lubrication (MQL) machining. The introduction of coolant techniques such as near-dry machining so called minimum quantity lubrication (MQL) and cryogenic coolant have shown promising performances especially in terms of cutting tool life. Nowadays, MQL is widely used in machining performances.

Keywords: Minimal quantity lubrication, ionic liquids, lubricants and machine.

1. Introduction

The various condition of machining which are dry machining near dry machining so called minimum quantity lubrication (MQL) and cryogenic machining. In recent years, there are many researchers that have been doing researches about MQL technique.

The earliest cooling lubrication approach in grinding is flood grinding, in which large amount of grinding fluid is poured as a continuous feed flow into the grinding wheel and work piece interface. The excellent characteristic lubrication of grinding fluid enables it to form an oil film on the work piece surface and reduce frictional coefficient and grinding force between the grinding wheel and the work piece.

Grinding fluid also aids in lubricating, washing, removing debris, and rust protection. However, the increasing extensive application of grinding fluid results in considerable application costs. Moreover, leakage and volatilization of grinding fluid cause pollution and inflict hazards to the environment and the human body. Therefore, a cooling lubrication approach is necessary for ecological and clean production grinding process. Dry grinding is the earliest environmentally friendly grinding processing technique. Given that grinding fluid is not used, the technique is evidently more environment-friendly; however, the massive heat from grinding cannot be dispersed from the grinding surface instantly. Thus, the heat delivered to the grinding wheel and work piece base through the grinding surface results in a locally high temperature on the work piece surface and even burns. This phenomenon, which is mainly due to insufficient cooling and lubrication on the grinding surface, eventually causes poor work piece surface quality and short grinding wheel service life.

2. Minimal Quantity Lubrication

MQL machining applies MWF in the form of mist with compressed air and delivers it through spindle to the tool work piece interface for maximal lubrication and cooling. Compared to traditional wet processes, MQL requires only 10-100 mL/h which dependent on the particular cutting operations.

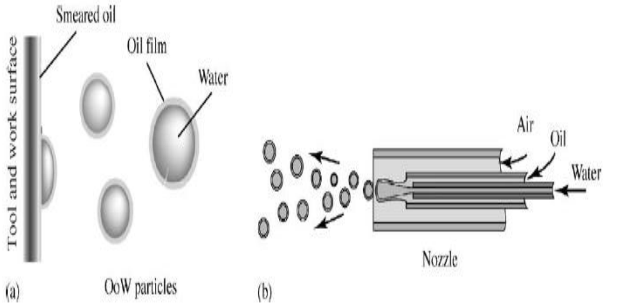

Figure 1: Principle of oil film on water droplets

Fundamental research in milling, turning, and drilling has confirmed that MQL can perform equally or even better than the wet condition in medium range of cutting processes, such as milling, shallow drilling on aluminum, cast iron, etc. However due to thermally-induced problems, it is still technically challenging for high-speed, high-energy cutting, such as grinding, deep-hole drilling, particularly for hard-to machine metals like compacted graphite iron (CGI), titanium alloys, and nickel-based alloys. To enable 100% implementation of MQL, automotive industry has started more proactively engaging in the MQL research and collaboration with academic institutes for developing the next-generation production processes.

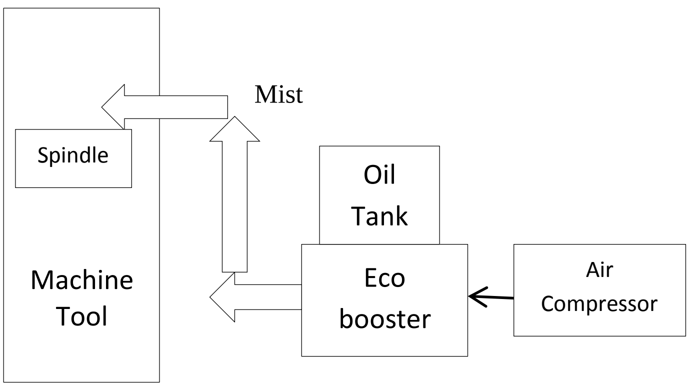

Figure 2: Block diagram for MQL System

Industrial experiences have concluded the advantages of MQL in power consumption, environment emission, waste; chips recycle value, safety, and flexibility as well as the major challenges including thermal issues expansion, wear, and firing, tool development through spindle/tool, and chips removal. The information is well-known in industry but rarely distributes to the academia and general population. As such, this paper aims to summarize the knowledge about the current status and future directions of MQL based on both industrial experience and academic studies in public domain.

3. Related Work

Hui Xing et al. in their paper predict and analyze accurately the lubrication characteristics and its influencing factors of marine sterntube bearings, coupling simulation between EHD (elastohydrodynamics) and MBD (multi-body dynamics) for sterntube bearings of marine diesel engine propulsion system. They found that the sterntube bearings were safe enough for normal operation; the vertical load and the total friction power loss on aft sterntube bearing were significantly higher than that of fore sterntube bearing.[1]

Dallwoo Kim et al. studied the friction of steel and cast iron pistons using the floating liner method. The secondary motion of each piston was carried out to analyze piston friction, and they found that the cast iron piston showed boundary lubrication at compression top dead center (TDC), caused by the larger tilting angle of the piston induced by the larger piston clearance and hydrodynamic lubrication conditions at TDC and BDC through each cycle were seen in case of steel piston, due to a good oil supply.[2]

Danilo de Jesus Oliveira et al. analyzed that the application of minimum quantity lubrication (MQL) in grinding has emerged as an alternative for reducing the abundant flow of cutting fluids, thus achieving cleaner production. He found that the effects of implementing the cleaning jet technique as a technological improvement of minimum quantity lubrication in grinding in order to reduce the usage of cutting fluids were positive and also reduced wheel wear when compared to the other cooling-lubrication methods.[3]

Salmiah Kasolang et al. had a study on pressure distribution around the circumference of a journal bearing and fluid frictional force of the bearing caused by shearing actions and the observations told that the location of the maximum pressure for the given operating conditions is close to the predicted value.[4]

M. De La Cruz Et Al. analyzed that Noise, vibration and harshness (NVH) refinement as well as thermo-mechanical efficiency are the key design attributes of modern compact multi-speed transmissions. He further analyzed that the thermo-mechanical efficiency is dominated by the engaged gears, with simultaneous meshing of teeth pairs subject to thermo-elastohydrodynamic regime of lubrication, with often quite thin films, promoting asperity interactions. [5]

Guy Bayada et al. studied that Stokes equation with pressure dependence of viscosity through Barus law, a new Reynolds model for line contact lubrication problems can be deduced, in which the cavitation phenomenon can also be considered and thus a new complete model consists of a nonlinear free boundary problem can be associated to the proposed new Reynolds equation.[6]

Evelyn George et al. observed that retention of lubricant during sliding of mating surfaces is one of the major problem faced in components of industry and the engine efficiency is affected by the frictional losses in engine liner-piston ring interface. Good lubrication can be achieved by making oil pockets on component surface, which leads to mixed lubrication regime.[7]

X.Y.Dong et al. studied the behavior of antifriction and wear resistance of Al2O3/Al2O3 ceramic friction pairs lubricated by four different lubrication oils under ultrasonic vibration and found that ultrasonic vibration would improve the behavior of antifriction and wear resistance of the Al2O3/Al2O3 ceramic friction pairs under various lubrication oils moreover the improving would be dramatizer when the viscosity of lubrication oil was low.[8]

Z.H. Nazri et al. observed that the bio-based lubricant has a great potential as a substitute for conventional lubricant in industries and the results show that at constant speed, the mineral oil exhibits higher value of dynamic pressure than the bio-based lubricant and also the mineral oil carried more load compared to bio-based lubricant and finally concluded that the bio- based lubricant exhibits significant behavior in protecting the surfaces from wear and damage.[9]

M. Shahabuddin et al. investigated the friction and wear characteristics of Jatropha oil based bio lubricant and observed that the addition of 10% jatropha oil with base lubricant can be used as lubricating oil which would help to reduce the global demand of petroleum based lubricant substantially.[10]

Mohd Fadzli Bin Abdollah et al. studied the effect of gas lubrication on friction behavior of bearing material, which is carbon chromium steel by employing taguchi method. The experiments shows that gas blown to the sliding surfaces in air effectively reduced the coefficient of friction as compared to the air lubrication and the N_2-gas lubrication reduced coefficient of friction by 24%.[11]

Muhamad Noor Harun et al. studied the wear factor based on lubrication performance and found that wear factor was a function of lambda ratio, which was correlated with femoral head size and diametral clearance.[12]

D. Md Razak et al. investigated the influence of lubricant on Acrylonitrile Butaiene Styrene (ABS) curve surface structure (CSS) sliding against ball bearing and used palm oil as lubricant and found that the measured friction using palm oil is lower than the mineral oil. [13]

S.M. Hafis et al. evaluated the effects of minimum quantity lubrication on the deformation of aluminum work piece over a tool and observed the load displacement behavior during the steady state condition and that significant differences exist between lubricant quantity, load-displacement distribution and surface finish of the product was shown.[14]

Mohamad Syahmi Shahrom et al. investigated the Minimum Quantity Lubricant (MQL) and wet machining in milling processes and determined the effect of lubrication conditions on the surface roughness and finally observed that MQL produced better surface finish as compared to wet machining and the result can significantly reduce cost and environmental pollution. [15]

Mohamad Ali Ahmad et al. determined the effect of oil supply pressure at different oil groove positions on torque and frictional force in hydrodynamic journal bearing and found that oil supply pressure and groove positions had affected the frictional force and torque in journal bearing.[16]

Flávia Aparecida de Almeida et al. studied the wear and friction behavior of self-mated silicon nitride pairs in lubricated ball-on-flat reciprocating sliding conditions using diesel fuel and soy- bean biodiesels as lubricants and found that the friction coefficient is considerably higher for the diesel fuel than for biodiesels and observed that the wear mechanisms were mainly mechanically dominated.[17]

Ibrahim Deiab et al. observed the effect of six different strategies on the flank tool wear, surface roughness and energy consumption during turning of titanium Ti-6Al-4V using uncoated carbide tool at certain speed and feed and found that the use of rapeseed vegetable oil in MQL and MQCL configuration turns out to be an overall sustainable alternative and the use of vegetable oil as a lubricant for machining.[18]

Kedare S. B. et al. studied the effects of three parameters, namely, cutting speed, feed and depth of cut upon Surface Finish during milling operation and found that the surface finish was improved by 27% and also showed that MQL may be considered to be an economical and environmentally compatible lubrication technique.[19]

Jayaseelan.V et al. analyzed that when friction occurs between tool and work piece fractionize with each other, surface expansion and high normal pressure occurs even at elevated contact temperature between work piece and die, which leads to adhesions (cold-weld), abrasion of die and work material and a lubricant is used to reduce the friction and determined the frictional factor for both un-lubricated and lubricated conditions.[20]

Paolo C. Priarone et al. studied the influence of the lubrication strategy on tool wear, surface quality and environmental impact when milling and turning Ti-48Al-2Cr-2Nb (at. %) intermetallic alloys and found that dry machining requires a sensible reduction of process parameters to preserve a stable process, although limiting the energy consumption and reducing to zero the lubricant consumption.[21]

Bruce L. Tai et al. summarizes the advancements and challenges of minimum quantity lubrication (MQL) technology in automotive powertrain machining, they observed that Elimination of coolant systems creates significant saving from energy and equipment, the flexibility to relocate the machines, reduction of waste stream and floor space, and a cleaner and healthier work environment.[22]

J. Fleischer et al. studied a methodology for reducing the energy demand and increasing the lifetime of ball screws by minimizing the friction torque with adaptive lubrication and deals with the lifetime of ball screws with standard lubrication and new adaptive lubrication aims at proving the increase of the lifetime.[23]

Zhang Dongkun et al. studied that nanoparticles with the anti-wear and friction reducing features were applied as cooling lubricant in the grinding fluid and found that he specific grinding energy and the work piece surface roughness initially increased and then decreased as MoS_2 nanoparticle volume concentration increased and satisfactory grinding surface lubrication effects were obtained with 2% MoS_2 nanoparticle volume concentration.[24]

V. García Navas et al. observed that the high strength alloys are difficult to machine due to the high temperatures generated during cutting so they compared the surface integrity (roughness, hardness, residual stresses and microstructure) generated in AISI 4150 (50CrMo4) steel by dry turning, turning with lubricant (oil based emulsion) and cryogenic turning with LN_2 and found that cryogenic machining is the best solution since it reduces machining problems of heating, leading to tool life improvement and better surface integrity of turned components.[25]

Adil Muminovic et al. studied the mathematical model for solution of lubrication problem in case of mixed friction, i.e. when total contact load of two bodies is partially transmitted through the peaks of roughness of a solid contact, and partly through the pressure generated in the oil film and developed a computer program which enables rapid analysis of tribological parameters at the point of contact of two bodies (the thickness of the oil film, the pressure transmitted by solid body, the pressure transmitted by fluids, temperature in the oil film) in the function of working conditions parameters.[26]

Takayuki Hama et al. investigated a variation of lubrication condition on die surface during square cup sheet hydroforming and further investigated he difference in the lubrication condition depending on a position on the die surface, some holes were made on the die surface to let the pressure medium flow out through the holes during the process and found that he lubrication condition was different depending on the position on the die surface.[27]

E. A. Rahim et al. experimentally found that the application of MQL based synthetic ester as the cutting fluid was more efficient for the machining process as it reduced the cutting temperature, cutting force, tool-chip contact length and produced better chip thickness compared to dry machining technique.[28]

Gyanendra Singh Goindi et al. observed that the presence of even minute quantities of ionic liquids could significantly affect the machining process through reduction in cutting forces and surface roughness of the machined work piece, as compared to dry cutting, conventional flood-cooled cutting, and MQL machining with neat vegetable oil.[29]

S.Kolahouz et al. studied minimum quantity lubrication as a sustainable lubrication method in machining processes, improved energy consumption, experimental impact, personal health, while enhancing the machining affected zone properties in comparison with floating method.[30]

Mohamed Handawi Saad Elmunafi et al. studied that use of cutting fluids in machining processes can reduce the cutting temperature and provides lubrication to tool and work piece, which increases tool life and improves the surface quality. They used vegetable oil as cutting fluid because of its superior lubrication and high-pressure performance and found that MQL can be a good technique for turning hardened stainless steel using coated carbide cutting tools for cutting parameters.[31]

4. Auto Lube System

Auto lube systems have many advantages over traditional methods of manual lubrication:

- All critical components are lubricated, regardless of location or ease of access.
- Lubrication occurs while the machinery is in operation causing the lubricant to be equally distributed within the bearing and increasing the machine's availability.
- Proper lubrication of critical components ensures safe operation of the machinery.
- Less wear on the components means extended component life, fewer breakdowns, reduced downtime, reduced replacement costs and reduced maintenance costs.

- Measured lubrication amounts mean no wasted lubricant.
- Lower energy consumption due to less friction.
- Increased overall productivity resulting from increase in machine availability and reduction in downtime due to breakdowns or general maintenance.

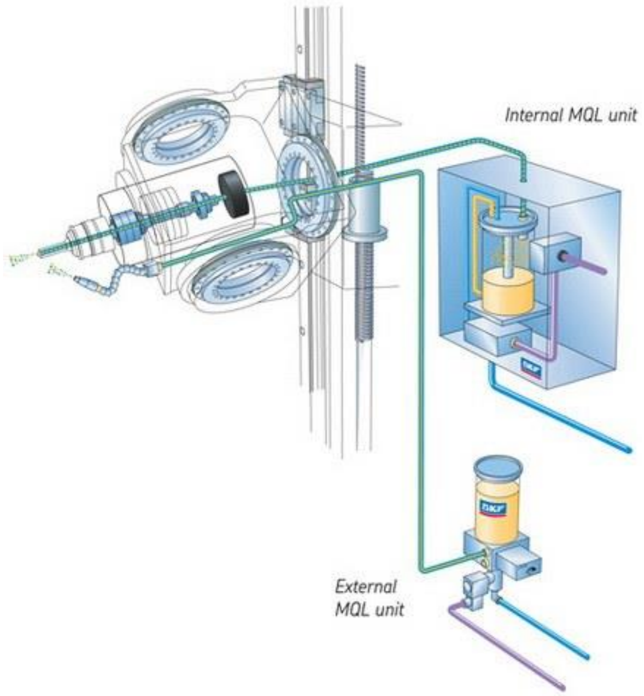

Figure 3: FLOC component for Lubrication

5. Conclusion

The conclusions are MQL shows the better surface roughness compare with wet machining. It increases the availability, performance efficiency and the quality rate, results in improvement of the overall effectiveness. The effects of minimum quantity lubrication during the cold work metal forming process on load-displacement and surface finish of the product were examined and compared. MQL can be a good technique to turning hard stainless steel using coated carbide cutting tools up to 170 m/min and 0.24 mm/rev. It was found to be a more sustainable alternative to synthetic cooling in terms of tool wear, surface quality and cutting energy consumed combined. Also that the booster pumps required for the small flow of vegetable oil and air mixtures are way lighter than the pumping system required for flood cooling technique. Although flood cooling technique is the more prevalent practice in the industry these days, this study shows that it is feasible to use the sustainable alternative of vegetable oil, especially at feeds and speeds close to 0.1 mm/min and 90 m/min respectively, for Titanium. This means it would be sustainable by default for softer metals and alloys. The application of cooled air as a lubricant also appeared to be effective as presented in the literature. Especially when compared with dry machining, it turns out to be a good alternative. However, machining under MQL seems to be limited by cutting temperature, because at high speed the effect of oil mist becomes evaporated.

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